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THE CHRONOLOGIC AND GEOGRAPHIC RANGE OF DESMOSTYLIANS

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AND
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DAVID K. CALDWELL
Editor

THE CHRONOLOGIC AND GEOGRAPHIC RANGE OF DESMOSTYLIANS[1]

By Edw. D. Mitchell, Jr.[2]
and
Charles A. Repenning[3]

Abstract: This study attempts to summarize the scattered literature on desmostylian ranges, and in addition presents new data for early, middle, and late Miocene records of *Desmostylus* and a late Miocene record of *Paleoparadoxia*. Based on new data and a literature review, we believe the following ranges are valid: *Desmostylus* ranges from early Miocene, or possibly late Oligocene, to late Miocene; *Paleoparadoxia* ranges from early to late Miocene; *Cornwallius* is confined to the early Miocene; and *Vanderhoofius* is confined to the middle Miocene. Both *Desmostylus* and *Paleoparadoxia* are circum-North Pacific in distribution, whereas *Cornwallius* and *Vanderhoofius* are restricted to the eastern North Pacific. More than one desmostylian genus may be found in the same bed, and in the late Miocene of California both sirenians and desmostylians occur together.

Introduction

Desmostylians were heavily built, quadrupedal, amphibious mammals, apparently confined to the shores of the North Pacific basin largely during the Miocene Epoch. Fossils of desmostylians are found from the southern islands of Japan northward to Sakhalin, Kamchatka, and Alaska, thence southward to British Columbia, Washington, Oregon, California, and Baja California. Their bones and teeth are usually found in littoral marine deposits.

Marsh (1888), in the original description of the genus *Desmostylus*, included it in the Sirenia, and desmostylians have been most commonly so grouped since then. However, others have suggested relationships with multituberculates (Abel, 1922), proboscidians (Osborn, 1902), and perissodactyls (particularly tapirs; Ijiri and Kamei, 1961). Reinhart (1953) separated the Desmostylia from the Sirenia by raising the group to ordinal status, and related the Desmostylia to both sirenians and proboscidians through a hypothetical Paleocene paenungulate ancestor (Reinhart, 1959).

Since V. L. VanderHoof (1937) monographed desmostylians, it has been generally thought that "the stratigraphic range of *Desmostylus* appears to be strictly limited to Temblor and Briones time; that is, upper Middle Miocene and lower Upper Miocene" (VanderHoof, 1937: 195). This belief in the restricted range of *Desmostylus* (in the eastern North Pacific) still persists

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despite Remington Kellogg's statement, six years before VanderHoof's publication, that *Desmostylus* is "found in formations varying in age from lower to upper Miocene" (Kellogg, 1931: 226). Although Kellogg cited localities in San Luis Obispo and Orange Counties, California, he provided no additional details for early Miocene records (1931: 224).

It is our intent in this paper to give complete data documenting examples of early, middle, and late Miocene records of *Desmostylus* in the eastern North Pacific and to summarize the geographic and chronologic ranges of all other desmostylians now known to us. In addition, we present data on a new record of *Paleoparadoxia* from the late Miocene of California, and on the association of desmostylians and sirenians in central California.

In compiling our summary of records, we have used the following cheek tooth characters in the identification of desmostylian genera:

Desmostylus: Columns of cheek teeth closely appressed, usually polygonal in cross section, cingulum absent, enamel base not swollen, column height about three times diameter of column.

Cornwallius: Columns of cheek teeth not closely appressed, circular in cross section, cingulum may be present but never surrounds entire tooth, enamel base may be swollen, column height about one to two diameters of column.

Paleoparadoxia: Columns of cheek teeth may or may not be appressed, polygonal or circular in cross section, cingulum may be present and may surround entire tooth, enamel base swollen, column height forms about half of crown height.

Vanderhoofius: Cheek teeth of *Vanderhoofius* are unknown.

We regard *Kronokotherium* Pronina (1957) from Kamchatka and *Desmostylella* Nagao (1937) from Japan as synonyms of *Desmostylus,* and follow VanderHoof (1937:191-192) and Reinhart (1959:66) in not considering *Neodesmostylus* a desmostylian.

We have attempted to treat all desmostylian records here by a uniform set of standards so that the relative age of the occurrences can be seen. The boundaries of epochs used are those of Weaver, *et al.* (1944) for marine metazoans, except that the Miocene-Pliocene boundary is placed at the top of the Neroly Stage. This usage does not agree with epochal boundaries used by Weaver, *et al.* (1944) for foraminiferal stages, with those used by Wood, *et al.* (1941) for North American mammalian ages, or with the epochal correlations customarily employed in Japan. This will explain our seeming departures from some previous age assignments. We have had to rely entirely upon the statements of Japanese workers as to the age of Japanese desmostylian records.

Correlation between marine metazoan stages of western North America, foraminiferal stages of the same area, mammalian ages of North America, European Miocene and Pliocene stages, and Japanese formational correlations (most commonly correlated with European stages, but sometimes with North

American stages), and the epochal assignments arbitrarily used with them are indicated in Table 1. No single chronology along the western side of the North Pacific is in wide use. The stages shown on Table 1 for the Japan area represent a composite of names proposed by Takai (1939), Makiyama (1940), and Tai (1959), with correlations made by these authors and by Asano (1958), Hatai (1960), Watanabe (1953), Yabe (1959), and Ijiri and Kamei (1961). In the following discussion we try to clearly specify whether we are referring to a formation or a stage.

Table 1 also shows the range in time of occurrences of desmostylian and sirenian fossils in the North Pacific basin. Insofar as possible the fossil occurrences have been placed on the chart on the basis of evidence of age independent of any significance that might be given to the desmostylian and sirenian fossils. For the most part this evidence has been based on either foraminifera or molluscs and echinoids. A few records were also associated with land mammals.

The following abbreviations are used in the text: UCMP–Museum of Paleontology, University of California, Berkeley; USGS–United States Geological Survey; and USNM–United States National Museum.

DESMOSTYLIAN RANGES

Genus **DESMOSTYLUS** Marsh, 1888

CALIFORNIA–Teeth of *Desmostylus* are moderately common fossils in rocks of middle Miocene age in California (the Temblor Stage of Weaver, *et al.*, 1944). It is not the object of this report to place all discoveries on record but only to document one record of unquestioned age and identity for each stage in which one or more records are known. Because early, middle, and late Miocene records are known from one area in California (the Cuyama Valley area of San Luis Obispo and Santa Barbara Counties), these are given here, although records from other areas might be equally appropriate. Our California teeth all fall within the range of variability of *D. hesperus*, as V. L. VanderHoof (1937) interpreted the species.

Early Miocene

Material: USNM 22922 and USNM 22923: Two incomplete cheek teeth (Fig. 1).

Collector: John G. Vedder, 1960.

Locality: USGS vertebrate locality (Menlo Park register) M1028: In bed of stream midway along a northwest-trending reach of a small drainage in the Caliente Range, San Luis Obispo County, California, 4.3 miles northwest of the town of New Cuyama, Santa Barbara County, California. The locality is 1.05 miles east of the west edge and 0.25 mile south of the north edge of the Cuyama Ranch 7.5-minute U.S. Army quadrangle, 1943 edition.

Formation and Age: Painted Rock Sandstone Member of the Vaqueros Formation (terminology of Hill, Carlson, and Dibblee, 1958), early Miocene:

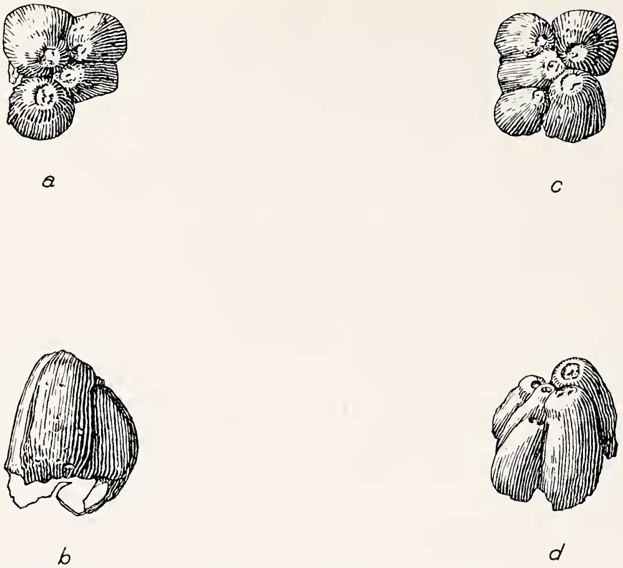


Figure 1. Desmostylus, cf. *D. hesperus,* occlusal (a) and side (b) views of cheektooth USNM 22922; and occlusal (c) and side (d) views of cheektooth USNM 22923: both from early Miocene of Cuyama Valley area, California. One-half natural size.

Vaqueros Stage of Weaver *et al.* (1944), Saucesian Stage of Kleinpell (1934), and Arikareean Age of Wood, *et al.* (1941).

Remarks: Vedder described the occurrence as being in a coquinoid bed containing barnacle fragments and *Lyropecten miguelensis* (Arnold). In the same area stratigraphically higher beds contain a large fauna from which Vedder reported *Turritella inezana altacorona* Loel and Corey, *Rapana vaquerosensis* (Arnold), and *"Crassatella" granti* (Wiedey). Underlying and overlying strata contain Saucesian foraminifera according to Hill, Carlson, and Dibblee (1958:2987). Beds containing the same marine fauna farther east in the Caliente Range are interbedded with continental sediments containing a mammalian fauna assigned to the Arikareean Age by Repenning and Vedder (1961). The molluscan faunal associations above and below the *Desmostylus* teeth suggest an early Miocene age (Vaqueros Stage) in the West Coast standard chronology.

Middle Miocene

Material: USNM 22925: An incomplete cheek tooth (Fig. 2).

Collector: John G. Vedder, 1961.

Locality: USGS vertebrate locality (Menlo Park register) M1030: 5.2 miles southwest of town of New Cuyama, on the south side of Cuyama Valley, Santa Barbara County, California. This is 0.2 mile west of the east edge and

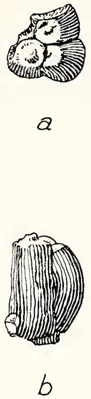


Figure 2. Desmostylus, cf. *D. hesperus,* occlusal (a) and side (b) views of cheek-tooth USNM 22925 from the middle Miocene of Cuyama Valley area, California. One-half natural size.

6.9 miles south of the north edge of the McPherson Peak 15-minute U.S. Army quadrangle, 1943 edition.

Formation and Age: Lower part of the type section of the Branch Canyon Formation (terminology of Hill, Carlson, and Dibblee, 1958) middle Miocene: Temblor Stage of Weaver, *et al.* (1944); Relizian Stage of Kleinpell (1934); Hemingfordian or Barstovian Age of Wood, *et al.* (1941).

Remarks: According to Vedder, the *Desmostylus* remains were associated with very poorly preserved echinoids that may be referred to *Vaquerosella andersoni* (Twitchell). Vedder further stated that beds in the same stratigraphic position in the same area contain *Aequipecten* cf. *A. andersoni* (Arnold) and *Amusium lompocensis* (Arnold)?, and that beds several feet below the *Desmostylus* locality contain *Turritella ocoyana* Conrad, *"Trophon" kernensis* Anderson, *Ficus (Trophosycon) ocoyana* (Conrad)?, *Bruclarkia* cf. *B. oregonensis* (Conrad), *"Phos" dumbleanus* Anderson (in Hanna), *Oliva californica* Anderson, and *Scaphander* cf. *S. jugularis* (Conrad). The underlying shaly strata contain Relizian foraminifera according to Hill, Carlson, and Dibblee (1958:2992), and to the north, in the eastern Caliente Range, strata with a similar marine molluscan fauna are interbedded with continental beds containing mammalian faunas of both Hemingfordian and Barstovian Ages (Repenning and Vedder, 1961). The combined molluscan fauna associated with or below the *Desmostylus* occurrence suggests a middle Miocene age in the West Coast standard chronology. *Desmostylus* is a common fossil in beds of the Temblor Stage in many parts of California.

Late Miocene

Material: USNM 22924: An incomplete cheek tooth (Fig. 3).

Collector: John G. Vedder, 1961.

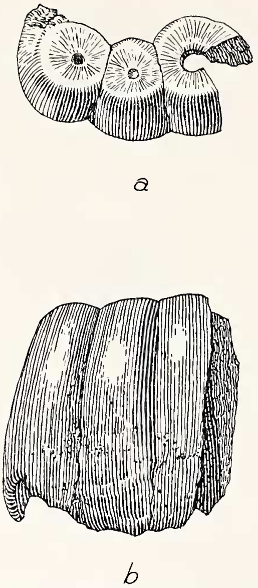


Figure 3. Desmostylus, cf. *D. hesperus,* occlusal (a) and side (b) views of cheek-tooth USNM 22924 from the late Miocene of Cuyama Valley area, California. One-half natural size.

Locality: USGS vertebrate locality (Menlo Park register) M1029: On the south side of Cuyama Valley, along northeast limb of anticlinal valley east of Branch Canyon, 4.7 miles south southwest of the town of New Cuyama, Santa Barbara County, California. This is 1.5 miles east of west edge and 0.8 mile north of south edge of Cuyama Ranch 7.5-minute U.S. Army quadrangle, 1943 edition; 0.29 mile east southeast of the termination of the road as shown on this map.

Formation and Age: In the highest part of the Branch Canyon Formation (terminology of Hill, Carlson, and Dibblee, 1958) near the type section, late Miocene: Cierbo or Neroly Stage of Weaver, *et al.* (1944); Barstovian or Clarendonian Age of Wood, *et al.* (1941).

Remarks: According to Vedder the *Desmostylus* remains were associated with abundant echinoids which Richard C. Allison, of the University of California, has identified as almost all *Astrodapsis cuyamanus* Kew, with the possibility of another form being represented by a small specimen. Stratigraphically above the *Desmostylus* locality are beds with a molluscan fauna from which Vedder reported *Turritella carrisaensis* Anderson and Martin. Coquinoid beds underlying the *Desmostylus* locality contain abundant echinoids which Eaton, Grant, and Allen (1941) assigned to the lower Neroly and Cierbo Stages. Several tens of feet below the locality Vedder reported the occurrence of a fauna which contains *Astraea* cf. *A. raymondi* (Clark), *Agasoma sinuata*

(Gabb), *"Trophon"* cf. *"T." carisaensis* (Anderson), *"Trophon" gillulyi* Grant and Eaton, *Lyropecten crassicardo* (Conrad), *Lyropecten estrellanus* (Conrad), and *Aequipecten* cf. *A. pabloensis* (Conrad). These mollusks suggest a late Miocene age in the West Coast standard chronology. Repenning has collected sirenian remains from this unit. Sirenians are common in the late Miocene of California, but are apparently unknown in earlier deposits. On the north side of Cuyama Valley in the eastern Caliente Range, strata containing a meager fauna including a few of these mollusks are interbedded with continental beds containing a mammalian fauna asssigned a Barstovian Age by Repenning and Vedder (1961). However, this marine molluscan fauna is also found interbedded with strata containing mammals that have been assigned a Clarendonian Age in other parts of California (see Savage, 1955:15) so that the correlation of this record of *Desmostylus* to the sequence of North American mammalian ages is not certain.

The correlation of these beds with the Cierbo and lower Neroly Stages by Eaton, Grant, and Allen would suggest an occurrence of *Desmostylus* somewhat younger than the youngest record cited by VanderHoof, which he referred to the Briones Stage. However, more recent consideration of the "Briones" record cited by VanderHoof (1937:197, UCMP locality V-3108) has led C. A. Hall to believe that the locality is in rocks "more probably assignable to the Cierbo formation" and that "the range of *Desmostylus* might be extended to the upper Upper Miocene" (Hall, 1958:23, 50).

Desmostylus teeth seen by Repenning in private collections have been collected from the Felton local fauna near Santa Cruz, California (UCMP locality V-5555) and were found in association with primitive *Hipparion* horses (of probable early Clarendonian Age) and two teeth of cf. *Paleoparadoxia* now in the Museum of Paleontology at the University of California (UCMP 45274 and 63981). Also associated in the same beds in the area of Santa Cruz are many specimens of the sirenian *Halianassa vanderhoofi* Reinhart. Vanderhoof (1941) compared this sea cow with European forms of Tortonian age. The association with *Hipparion* would tend to favor a younger age, perhaps Sarmatian. According to recent stratigraphic studies by Joseph C. Clark, of Stanford University, marine mollusks and echinoids of late Miocene age are found within the same unit and about 40 feet above VanderHoof's sea cow locality, although other specimens of sea cows are found throughout the unit and the horse and *Desmostylus* teeth also seem to be scattered throughout the unit. Overlying strata contain a Pliocene marine mollusk fauna.

In summary, *Desmostylus* records in California indicate a range from the Vaqueros Stage of the early Miocene to the Cierbo or Neroly Stage of the late Miocene.

OREGON—The only records of *Desmostylus* from Oregon are from the Astoria Formation, principally in the vicinity of Newport. As has been known for years (see VanderHoof, 1937:202), they are associated with marine mollusks of the Temblor Stage. Recently Douglas Emlong of Gleneden Beach, Oregon, found part of a skull of the rhinoceros *Aphelops* associated with *Desmostylus* remains in the Astoria Formation about 4 miles north of Newport, making possible an estimate of the age in North American land mammal terms. The rhinoceros represents a Hemingfordian to Barstovian stage of evolution within the Rhinocerotidae. The specimen is now in Mr. Emlong's private museum.

WASHINGTON—The only record of *Desmostylus* from the state of Washington seems to be that cited by Kellogg (1931:226) from the "upper Miocene Montesano formation" near the town of Vesta in Grays Harbor County. According to Howard D. Gower of the U.S. Geological Survey, the brief locality and lithologic description given by Kellogg indicates that the specimen came from the upper part of the Astoria Formation, which may be equivalent to the basal conglomeratic part of the Montesano Formation to the north (personal communication, 1963). Recent studies by Warren O. Addicott, also of the U.S. Geological Survey, indicate that the molluscan fauna at this locality is late Miocene in age (personal communication, 1963).

WESTERN NORTH PACIFIC—*Desmostylus* records are abundant in the Miocene on the Asiatic side of the North Pacific basin. The genus is known from Kamchatka (as *Kronokotherium,* Pronina, 1957), Sakhalin, Hokkaido, and Honshu (see detailed summaries of Yabe, 1959; Hatai, 1960; and Ijiri and Kamei, 1961). These records range throughout the Miocene although only two records of late Miocene age are cited by Ijiri and Kamei (1961:16, table 1), both from Honshu. The oldest records of *Desmostylus* appear to be from southern Sakhalin and Hokkaido, where associated foraminifera indicate a correlation with the Zemorrian Stage according to Asano (1958:45, 47). This age assignment is reviewed by Yabe (1959) and indicates a correlation with either the earlier part of the Vaqueros Stage or the Blakeley Stage, as these correlations are currently understood. By the definition of the Miocene used here, this is most likely earliest Miocene but could be of latest Oligocene age; it appears to be older than the earlier Miocene record from the Caliente Range described here.

ATLANTIC OCEAN—Stenzel and Turner (1944) listed *"?Desmostylus"* in a Miocene fauna near Burkeville, Texas, and referred to it as a "sea cow." Floyd, Miller, and Berry (1958) mentioned "sea cow" also, but this was based on the statement of Stenzel and Turner (1944) and not on new material (personal communication, W. B. N. Berry, 1963). We have been unable to verify this record.

Genus **CORNWALLIUS** Hay, 1923

The holotype of *Cornwallius sookensis* was found in the Sooke Formation of Vancouver Island, British Columbia (Cornwall, 1922). In all, three teeth (Cornwall, 1922; Clark and Arnold, 1923) and the temporal bone (Hay, 1923:107) of *Cornwallius* are known from the Sooke Formation, which is considered to be of early Miocene age (Weaver *et al.,* 1944:597). This is the only record of *Cornwallius* which is datable on independent evidence with any degree of accuracy.

Teeth called *Cornwallius sookensis* have also been found near San Telmo Point in Baja California, Mexico (VanderHoof, 1942). The *Cornwallius*-bearing rocks at the Baja California locality were referred to the San Gregorio Formation by Durham (1950) and were considered lowest Miocene in the standard West Coast chronology by Durham and Allison (1960:56) on the basis of the *Cornwallius* teeth. No other control is available to date this record.

Byers (1959:289) stated that "Vertebrate-fossil remains, chiefly teeth, have been found . . . on the north side of Unalaska [Island, Alaska]. These teeth were identified by G. Edward Lewis . . . as those of *Cornwallius* sp., a marine mammal of early Miocene age." Drewes, *et al.* (1961:606) further commented on these bones and teeth: the "most significant specimen is a low-crowned cheek-tooth fragment with typical desmostylid cusps. The fragments probably are referable to a single animal of the genus *Cornwallius,* which is generally indicative of an early Miocene age, although identification as *Desmostylus* is possible."

MacNeil, *et al.* (1961: fig. 1) listed "*Cornwallius*-bearing beds on Unalaska" at the bottom of the Miocene in their correlation chart on the basis of Byers' (1959) statement. Little control for this age assignment is available other than the *Cornwallius* remains; they were associated with *Mya* sp. cf. *M. grewingki* Makiyama, a species which probably indicates a correlation to the Blakeley Stage according to F. S. MacNeil of the U.S. Geological Survey.

Insofar as we have interpreted published material from Japan, the genus has never been found on the western side of the North Pacific; all citations to *Cornwallius* from the western Pacific appear to be referable to either *Desmostylus* or *Paleoparadoxia.* However, Fuyuji Takai (of Tokyo University) left two photographs with Donald E. Savage (of the University of California) of a specimen collected near Nagoya, Honshu that appears to be referable to *Cornwallius.*

Genus **VANDERHOOFIUS** Reinhart, 1959

Only two specimens of *Vanderhoofius coalingensis* were listed by Reinhart (1959). One (mandible UCMP 39989) is the holotype and the other (mandible UCMP 39990) is the paratype; both are from UCMP locality V-4854 southwest of Coalinga, California. They were found in direct association with abundant teeth of *Desmostylus hesperus.* Reinhart gave the formation as "Upper member of Temblor sandstone." The associated molluscan fauna indicates a Temblor Stage assignment.

Genus **PALEOPARADOXIA** Reinhart, 1959

The type specimen of *Paleoparadoxia tabatai* is from Aikawa on the island of Sado, Japan, from near the base of the Turusi beds probably of middle Miocene age (Tokunaga, 1939). Ijiri and Kamei (1961:16) tabulated three Japanese records of *Paleoparadoxia,* all from Honshu (the island of Sado is off the west coast of Honshu). These are shown in their list as being from early, middle, and late Miocene localities.

A complete skeleton of *Paleoparadoxia tabatai* was found in the Miocene Yamanouchi Formation at Inkyoyama, Izumimachi, Toki City, Gifu Prefecture, Honshu (Ijiri and Kamei, 1961:26). This skeleton was found stratigraphically "near" the holotype of *Desmostylus "japonicus"* from Togari, Kani-gun, Gifu Prefecture, even though the two localities are about 3 km. apart (Yabe, 1959:49). The most important point here is that in a "broad sense the Izumi skeleton of *Cornwallius?* [=*Paleoparadoxia* of Ijiri and Kamei] and the Togari skull of *Desmostylus japonicus* . . . are from the same, Togari beds . . ." (Yabe, 1959:49).

Reinhart (1959) listed only two referred specimens from North America (mandible UCMP 40862 and tooth UCMP 32076). He stated (1959:97) that the "type specimen from Japan and U.C.M.P. no. 32076 were found in a littoral formation of middle Miocene age." The tooth (UCMP 32076) is from UCMP locality V-3301 (not V-3801 as stated by Reinhart), which VanderHoof (1937:201) considered to be "Temblor" in age. The exact locality and age of the mandible (UCMP 40862) is unknown. It is reported to be from the area of Santa Cruz, California, and Reinhart suggested that it is from the Santa Margarita Formation of late Miocene age. Two isolated teeth of *Paleoparadoxia* from the Santa Margarita Formation of the Santa Cruz area are in the collection of the Museum of Paleontology of the University of California. Because they represent the first definite record of this family in the late Miocene of the eastern North Pacific Ocean, their occurrence is described here.

Material: UCMP 45274, a complete tooth, and UCMP 63981, an incomplete tooth (Fig. 4).

Collectors: UCMP 45274 was collected by Eleanor and Gladys Pavey of Watsonville, California, in about 1952. UCMP 63981 was collected by T. E. McCaw of Santa Cruz, California, in about 1950 and was given to J. C. Clark of Stanford University who, in turn, donated it to the Museum of Paleontology of the University of California.

Localities: The two specimens were collected from different localities, about 2,000 feet apart, from the same formation. UCMP 45274 was collected from UCMP locality V-5555, a sand pit generally known as the Graham sand pit, which is located on the south side of Bean Creek one mile northwest of Camp Evers junction in Scotts Valley along the Lockhart Gulch Road, Santa Cruz County, California. UCMP 63981 was collected from UCMP locality V-4004, a sand pit formerly known as the Pacific Coast Aggregates Company sand pit and currently as the Santa Cruz Aggregates sand pit, which is located on the north side of Bean Creek and about 2,000 feet north-northwest of the Graham pit.

Formation and Age: The Santa Margarita Formation, latest Miocene: Neroly Stage of Weaver *et al.* (1944); Clarendonian Age of Wood *et al.* (1941); Mohnian or Delmontian Stage of Kleinpell (1934).

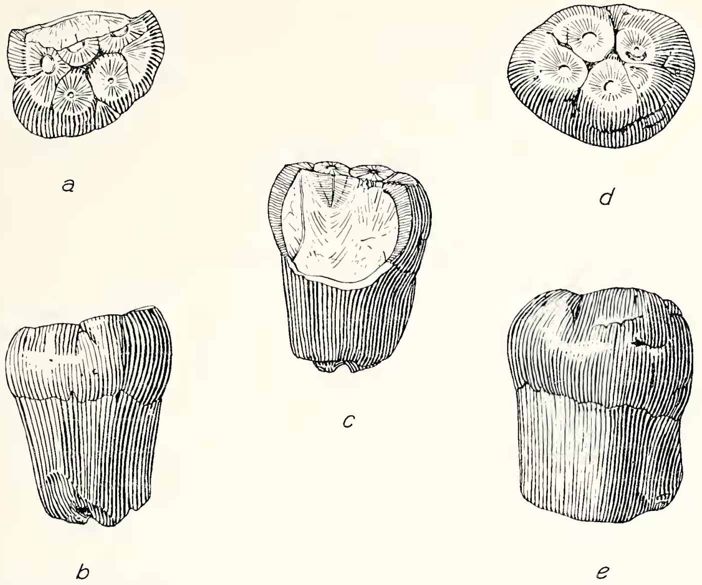


Figure 4. Paleoparadoxia sp., occlusal (a) and side (b, c) views of cheektooth UCMP 63981; and occlusal (d) and side (e) views of cheektooth UCMP 45274: both from late Miocene of Santa Cruz area, California. Natural size.

Remarks: Joseph C. Clark of Stanford University is currently engaged in a detailed study of the geology of the area which includes these localities. The following remarks are based largely upon his preliminary conclusions. In the Bean Creek area the Santa Margarita Formation contains scattered and in many cases wave-rounded teeth and bone fragments of sharks, birds, several land mammals including a primitive *Hipparion,* and marine mammals including *Desmostylus, Paleoparadoxia,* the sirenian *Halianassa,* cetaceans, and pinnipeds. Most of these fossils have been collected by private collectors during or following quarrying and screening of the unconsolidated sand that makes up the formation. For the most part there is no stratigraphic control of the occurrence of the vertebrate fossils in the formation. However, sirenian remains, seen in place at several localities by Repenning, occur as low as 15 feet above the base and as high as 40 feet below the top of the formation. The formation varies in thickness but at the localities here discussed is about 280 feet thick. There is no reason to think that the other mammalian remains are not scattered throughout the formation as are the sirenians.

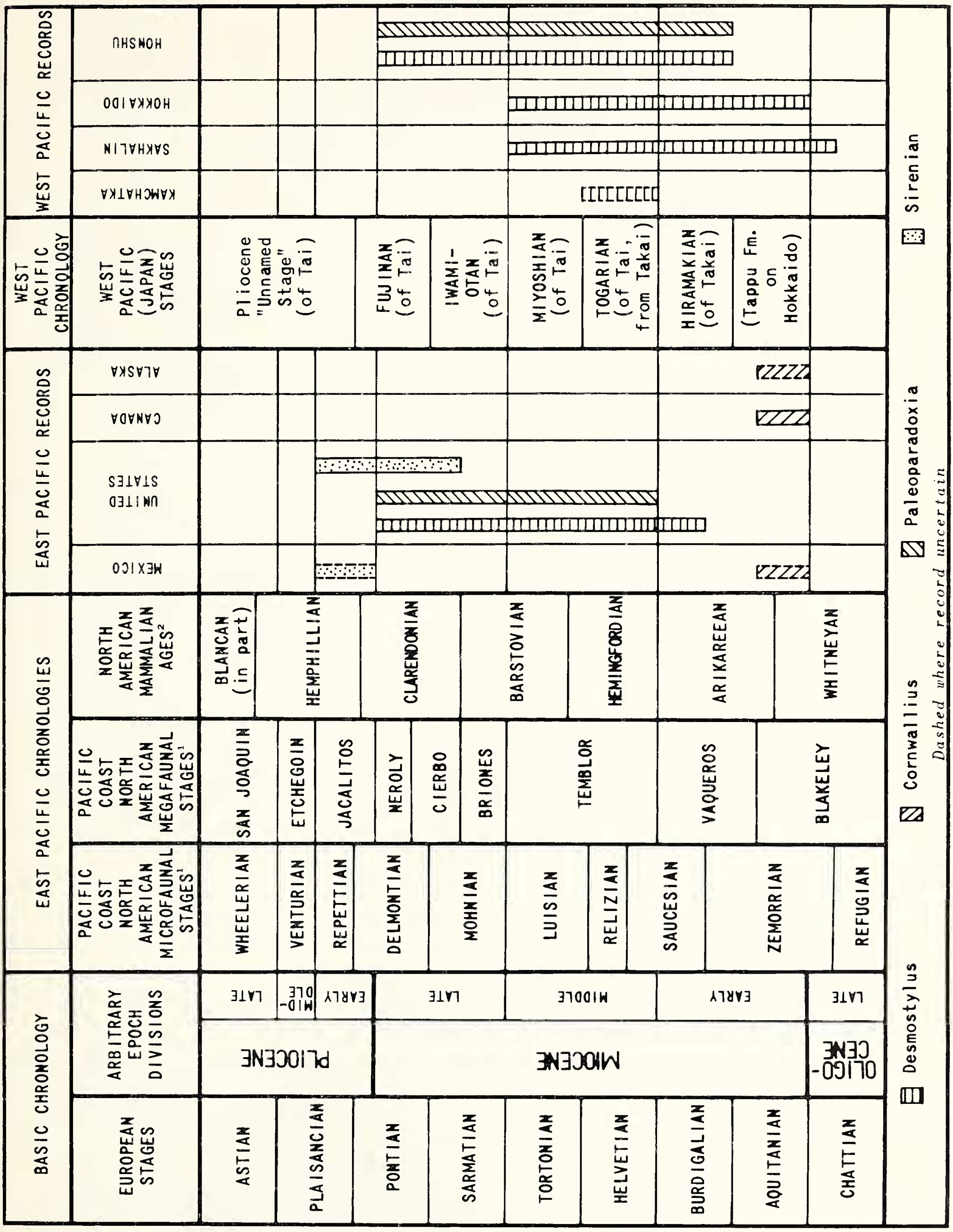
The little deformed Santa Margarita Formation rests with angular unconformity on folded and faulted marine beds containing foraminifera which indicate an early Luisian age. Clark has made several collections from the echinoid bed 40 to 60 feet below the top of the Santa Margarita. Provisional identification of these specimens includes *Lyropecten estrellanus* (Conrad) and *Astrodapsis spatiosus* Kew. The invertebrates are suggestive of a very late Miocene age (Neroly Stage). The siliceous mudstone unit conformably overlying the Santa Margarita Formation contains a meagre invertebrate fauna that is similar to the fauna of the lower part of the Purisima Formation of Pliocene age. Preliminary study thus suggests that the *Paleoparadoxia* and *Desmostylus* remains from the Santa Cruz area are of the latest Miocene age and occur very close to the Miocene-Pliocene boundary. The associated *Hipparion* indicates a Clarendonian age and the foraminifera in the underlying unit suggests that the Santa Margarita is younger than early Luisian age.

NORTH PACIFIC DESMOSTYLIAN AND SIRENIAN DISTRIBUTION

Sirenians are found in the Eocene of the Caribbean, and apparently have continuously occupied the Caribbean since then. Throughout much of the Eocene the Central American seaway provided free access between the Caribbean and the Pacific, as indicated by the similarity of marine invertebrate faunas and the endemism of the isolated South American nonmarine mammal fauna. There seems to be no reason to think that Caribbean sirenians did not also enter the Pacific basin, although no records of such entry are published. The paucity of records may be explained by the scarcity of marine Tertiary deposits on the Pacific side of Central America. F. H. Kilmer of the University of California, Santa Barbara, is presently working on a sirenian from the Miocene of Baja California that is presumably older than the late Miocene sirenians discussed below.

Kellogg (1925) described *Halianassa* (= *Metaxytherium*) *jordani* from diatomite deposits near Lompoc, California, which were mapped as Sisquoc Formation by Dibblee (1950: pl. 1). Kellogg stated that the sirenian was found at least 1,100 feet above the base of the diatomite and that it was "Sarmatian, or Upper Miocene" in age (1925:60). According to Dibblee, the lower 1,000 feet of the Sisquoc Formation is assignable to the Delmontian Stage, the remainder to early and perhaps middle Pliocene (1950:44). Other late Tertiary sirenians are known from western North America. Reinhart described a specimen (*Halianassa* sp.) from Baja California that was found in rocks "of early Pliocene age, but could be as old as middle Miocene" (1959:45). VanderHoof (1941) commented on a sea cow (*Halianassa vanderhoofi* Reinhart, 1959) from near Santa Cruz, California, and suggested that it was Tortonian in age. We favor a younger age for this record (see *Remarks* under Late Miocene record of *Desmostylus*). Reinhart (1959:44) reported that "the oldest sirenian reported from the Pacific coast of Central America is an Oligocene form from Chiapas, Mexico . . ." Mülleried (1932), who described the rib fragments upon which this record is based, stated that they were Oligocene in age. It may or may not be sirenian, but it does not appear to have lived in the Pacific basin because the marine Tertiary rocks of Chiapas were deposited by Caribbean waters northeast of the Sierra Madres according to J. W. Durham, of the University of California.

TABLE 1—CHRONOLOGIC RANGE OF DESMOSTYLIANS AND SIRENIANS IN THE NORTH PACIFIC OCEAN



[1] Weaver, et al., 1944

[2] Wood, et al., 1941

TABLE 1

Chronologic Range of Desmostylians and Sirenians in the North Pacific Ocean.

Northward, then, along the eastern shore of the North Pacific Ocean, there are few or no records of sirenians until they appear in late Miocene deposits in California. This is at the time when Olsson (1932) reported the beginning of endemism in the Pacific invertebrates of northern Peru, which until then had been clearly similar to Caribbean faunas of Trinidad. As has been discussed, the late Miocene contains the last of the records of desmostylians in the North Pacific basin.

SUMMARY AND CONCLUSIONS

In this paper we have followed recent usage among marine molluscan stratigraphers in arbitrarily selecting the top of the Neroly Stage and the middle of the Blakeley Stage as the limits of the Miocene Series on the west coast of North America. We have attempted to consider all pertinent desmostylian records in this chronologic framework. The generic assignment of some of these records is based on our interpretation of the taxonomic significance of tooth characters. Review of pertinent literature and documentation of new occurrences indicate that the following ranges are valid:

1. *Desmostylus* is circum-North Pacific in distribution; in the Japan area published records indicate that it could range in age from equivalents of the late Blakeley Stage (early Miocene) to equivalents of the Neroly Stage (late Miocene), and in North America it ranges in time from the Vaqueros Stage to the Neroly Stage. A record from the Vaqueros Stage is documented from Cuyama Valley, California, and late Miocene records are discussed or documented from Cuyama Valley and Santa Cruz, California, and from Grays Harbor County, Washington.
2. *Paleoparadoxia* is also circum-North Pacific in distribution; following Japanese workers, we now regard all previous records termed *Cornwallius* from the western North Pacific as representing *Paleoparadoxia.* The genus appears to have an early to late Miocene range in the western Pacific, and a middle to late Miocene range in the eastern Pacific. Late Miocene records are documented from near Santa Cruz, California.
3. *Cornwallius* is known only from a few fossils from early Miocene rocks in the eastern North Pacific. The genus evidently ranges from Alaska to Baja California in the eastern Pacific. Desmostylians referred to the genus *Cornwallius* from the western North Pacific are more probably referable to other genera.
4. *Vanderhoofius* is known only from the middle Miocene of California.

Based upon published records, sirenians do not appear in the eastern Pacific until the late Miocene. In the Santa Cruz and Cuyama Valley areas of California fossils of both desmostylians and sirenians have been found in the same beds. Sirenians have been found in eastern North Pacific Pliocene deposits.

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